The following is taken from Bill Mollison: *Permaculture Design Manual*

**Designers Checklist: *Soils***
1. It is a *primary* design strategy to prevent topsoil losses and to repair and rehabilitate areas of damages and compacted soils.

2. Permanent crop, soil, bunds, terraces, and low-tillage systems all reduce soil and mineral nutrient loss.

3. Soil rehabilitation and pioneer green crop should precede other plant system establishment (consider the addition of plants that offer elements of other essential nutrients)

4. Adequate soil test, plus test strips of crop examined for deficiency or excess symptoms, leaf analysis, and livestock health should be assessed to guide soil treatment

5. If soil types can be specified, fencing, cropping, and treatment should coincide with these specific soil assemblies, and specific crops for such type researched.

6. Soil life processes need to be encouraged by provision for green crop, humus, mulch, and the root associate (myrorrhiza) of plants. A useful earthworm may need to be introduced.

7. Drainage, hence pH soil water capacity, need specific treatment or assessment, and will largely determine crop and types.

8. Minimal use of large livestock and heavy machinery is to be recommended on easily0coimpacted soils, as is burning and clearing.

9. Use pigeon and animal manure where major elements are scare, as in third world areas (also use of greywater and sewage, or wastes). Before draining waterlogged soil, recommended crops to suit this condition. Never drain wildlife habitats, fens, or bogs which are spices-rich.

11. Choose the right soil-shaping or earthworks to suit crop drainage, and salt threat.

12. Using an auger, check soils for house foundations. Using a (wetter) soak pit, time the absorption of greywater for sewage disposal at house sites.

13. Preserve natural (poor) sites for their special species assemblies; pay most attention to human nutrition tin home gardens, and select species to cope with poor soil condition on the broad scale.

14. Fertilize plants using foliar sprays containing small amounts of the key elements, seeds with seed and foliar sprays are economical way to add nutrients to plants.

**Soils and Permaculture**

3 Goals for Soils in PC**:**

1. Stabilize and Conserve Soil
2. Assist soils in retaining their productivity
3. Condition soil

*Plants need soil* to meet their nutritional and structural needs

--Environmental preservation --human health and nutrition

-Conservation ever importance today because of Soil depletion: we are losing soil at an increasing rate. *Caused by human influence and natural causes* such as wind, water. Soil is being *depleted in structure and yield.*

--Places where soil is increasing:

 Uncut forests

 Under water at lakes and ponds in prairies and meadows with permanent plants

 …and where we grow plants with mulched or non tillage systems

**Soil Structure**

*--Soil consists of*

Soils consist of: minerals, soil water, gases (from atmosphere or breakdown of rocks), life forms/soil biota (fungus, bacteria, roots) and once living remains (humus of the earth, decayed/compressed fossil and organic materials)

*…And Soil is held together by* roots, clay, minerals and chemical bonds.

--The idea soil structure has a crumb like structure that aids in the bonding of chemicals and creates pore space. Organic materials hold the structure open in the rain and plant nutrients become soluble for absorption by roots

**The idea is to create living soil** Soil life is in indicator of healthy soil. *How can you increase soil life?*

--Organic material, mulch, green manure (cover crop)

--With a healthy and diverse soil system provides plants with many of the essential minerals will be the natural processes for creating healthy plants and nutritious food can occur.

--Creation of humus:

-*Humus i*s provided by the above ground mass of grasses, trees, plants, and natural mulches

*Soil Friends:* worms, fungi, newmatdoes, grubs, isopods, mites, amoeba, toads, spiders, ants, moles, snakes, centipedes, larva, maggots, etc.

*Mulching:* to add plant nutrients, buffer soil temperatures, prevent erosion, promote soil life, restore soil structure

 Select appropriately for minimal weed seed, residual pesticides, and for best effect on specific crops

Mulching not only enhances soil fertility, but protects soil as well. It is a primary strategy to prevent topsoil lose and to repair and rehabilitate soils. Low tillage systems reduce soil and mineral nutrient loss. When we aerate (plough, double dig) our soils we turn up the humus and minerals and oxidize them, therefore it gets lost in the atmosphere

--**Gases (N and O2) enter** the soil via pore space

Natural soil is a mosaic of aerobic and anaerobic patches called micro-sites where either oxygen (aerobic) or ethylene (anaerobic) sites develop. The cycle between ethylene and oxygen activates soil, it benefits plant growth and root stimulation, and inhibits microbial activity. Without ethylene plant nutrients become difficult to uptake. By minimally disturbing soil, surface mulch can act as a precursor for ethylene. By avoiding ploughing and digging the ideal conditions for the reaction between ethylene and oxygen can take form. Working with wet soil causes the soil to lose air.

-- **Soil structure is destroyed by** removing permanent vegetation, flooding, stocking sheep or cattle, fertilizers, burning…creates cemented, dusty, hydrophobic areas. Perennial low cultivation systems of forests and crops is the solution! Ideal: permanent pastures, forests, forest gardens, orchards with green crops as mulch, no dig or mulched beds.

**Soil Rehabilitation:**

*Water control*

--Raising soil water: swaling, contouring, terracing, loosening soils

--Decreasing waters: raised beds, deep drains, plant trees (transpiration)

*Soil Conditioning/ fertilizer*

*Crop and plant species selection*

*Building soil:*

--Strategies for Building soil

Raise or lower beds to facilitate watering or drainage

Mix compost or humus in the soil, supply clay, sand and nutrients to balance

Mulch to reduce water loss, sun affects, and erosion

**A few definitions**

Clay: Extremely fine. Sticky or greasy to the touch becomes hard and brick like when its dry. Requires large amounts of lime or alum to bring about desired changes in soils pH

Sand: minute rock fragments that make up the mineral portion of sand. Formed through the erosion of rock material

Loam: texture or class of soil that is sand, silt and clay

Humus: well decomposed vegetable and animal material capable of holding large amounts of plant nutrients and moisture

Lime: chemical compound containing calcium. Neutralizing and food properties, benefits soil structure.

Soil Notes from Dr Henry D Foth, A Study of Soil Science

**Soil components**

*Topsoil,* or horizon. A zone of organic matter accumulation and maximum biological activity

*Subsoil,* or “B horizon.” The clay, to a considerable extent, has been “washed” (because it is so fine) into the subsoil by downward percolation

*Parent Material,* or “C horizon.” Material only slightly altered during development of the soil.

--only 1/10 of the Earth’s surface is suitable for growing plants

-Mineral Particles 45%

1. Sand and silt particle weather and essential plant nutrients become soluble for plants

2. Clay particle are formed during weathering, and are very fine-sized. Clay provides most of the surface for adsorption of water and nutrients most soils.

-Pore Space 50%

1. Plant root live in pore spaces

2. Some water is stored in pores

3. Pores also contain oxygen needed for root respiration

4. Pores allow oxygen to diffuse into soil and excess water to drain away

-Organic Matter 5% Provides essential nutrients for plants when decomposed. Very important for nitrogen

2. Acts to make soils friable, easy to cultivate, and able to absorb water quickly

**Soil Particle Support Plant Life**

“When a plant seed falls to warm, moist soil several things happen. First the seed absorbs water and swells. The dormant miniature plant in the seed embryo comes to life. Respiration increases and food stored in the seed is digested. Soon the seed bursts open and the top and root portions of the embryo emerge from the seed. This borning of a plant is called germination. Soon tender leaves emerge from the soil then turn green and the plant begins to manufacture its own food. Food is what the plant manufactures in photosynthesis, for ex, carbohydrates. Nutrients are absorbed from the soil or obtained from the air and water. The food from the seed is exhausted. The plant is now on its own, dependent on the air of the atmosphere and water in the soil for carbon, hydrogen, and oxygen used to manufacture food by photosynthesis. The plant is dependent on the soil for the remaining 13 elements that it needs. Commonly, one of the 12 nutrients supplied form the soil particles limits the growth of plants.”

-Nutrients are absorbed by plant roots as ions

-Soil particles are sources of essential elements required in plant nutrition

-Soil serves as a digestive system for the plant

**Essential Plant Nutrients**

It is the presence of available nutrients that determine how plants will grow

-A fertile soil is one that is able to supply the complete dietary needs of the growing plant

-If some nutrients are absent the plant will show some characteristic sign of deficiency in its development, called “hunger signs”

**Primary Elements Required in Large Quantities**

The essential elements required in large quantities are as follows. They are absorbed by soil and plants and are supplied by:

-minerals released from the decomposition of native rock and the decomposition of organic matter

-deposition with the soil from flood waters

-application of limestone and commercial fertilizer materials

-use of animal or plant manures

*Nitrogen*: stimulates above-ground growth and produces the rich green color of healthy plants.

Infuses the quality of fruits and increases the protein content within fruits. Increases the plants utilization of other major elements is stimulated by the presence of nitrogen in the plant. Constitutes amino acids, nucleic acids, enzymes, and vitamins.

Sources: legumes, decomposition of organic matter

-while 80% of the atmosphere is N, most plants cannot utilize this “free” N. Legumes have the capacity of converting atmospheric N into a form that can be utilized by plants. N fixation happens because of a symbiotic association between plant root and Rhizobium bacteria in the soil. This process occurs in the nodules within plant roots

-excessive N can delay crop maturity, weaken stems, increase lodging, and produce excessive vegetation growth at the expense of fruit

*Phosphorus* (K): Necessary for hardy growth of plant and cell activity. Found in fruits and seeds and is the part of the roots that are involved in the uptake of water and nutrients. Plays role in the processing of energy such as formation of fat, the movement of food, and healthy seed. Increases resistance to disease (by stimulating rapid cell development)

-Desirable soil bacteria is stimulated by K

-Excesses K can result in low yields

-Cropping depletes K: crop rotation, give land a rest

*Potassium* (K): encourages development of healthy root system and offsets excessive N. Synthesizes starch and translocates carbohydrates. Enhances disease resistance by strengthening stalks and stems. activates enzymes within plans. contributes to thicker cuticle which guards against disease and water loss. controls turgor pressure which prevents wilting. enhances fruit size, flavor, texture, and developments. involved in production of amino acids, chlorophyll, starch formation and sugar transplant from leaves to root.

-Clay generally high in potassium

-Sands generally low

*Calcium*: A component of several other minerals. Deficiency is rarely a problem if soil is limed. Forms cell walls. Gives rigidity or stiffness to stems. Neutralizes acids. Stimulates root and leaf development Activates enzyme reaction involved in plant metabolism. Helps maintain optimum pH levels. Neutralizes organic acids as a result of the plants respiration. Reduces toxicity of manganese, zinc, and aluminum.

*Magnesium*: Calcium’s companion because the most common source is dolomitic limestone which contains calcium and magnesium. Working companion with phosphorus and stimulates the utilization (uptake) of phosphorus. Helps in starch translocation. Essential for formulation of chlorophyll. Formulates fats and oils.

*Sulfur*: Almost all sulfur is found on og. matter. Another source is rainfall. Sulfur oxides are produced from the combustion of fossil fuels. Produces plant proteins and plant hormones. Influences photosynthesis and protein synthesis. Found in enzymes and vitamins used in plant metabolism. Important in the formation of chlorophyll.

--Carbon, Hydrogen, Oxygen: sourced from water and carbon dioxide, absorbed from the atmosphere

**Micronutrients**

-Certain diseases are believed to be caused by deficiencies in micronutrients

-Increase food nutrition

*Manganese*: dependent on pH, organic matter, and aeration. Deficiency most likely in neutral or alkaline soils because it is less soluble at high pH levels. High manganese levels may appear as toxic in crops. In acidic sandy soils manganese may leach past root zone and become unavailable to the plant.

-Plays important role in metabolic process in plant

-Required for the formation of chlorophyll

*Iron*: Must be in soluble form. Only a fraction of total iron is available to plants. Application of ferrous sulfate or iron chelates can increase salt level. Slightly acidic soils can make iron more available.

-Catalyst in the formation of chlorophyll.

-Required in oxidation-reduction reactions in plants.

*Boron:* Deficiency results in low crop yields. Leached from the root zone in coarse soils.

- essential for seed germination

-required for cell wall formation

- involved in sugar transplant

-essential for protein synthesis

*Copper:* well drained sandy soils usually low in copper. Heavy clay soils generally abundant in copper.

-Necessary in formation of chlorophyll

-catalyst

*Zinc:* availability decreases as pH increases.

-promotes certain enzyme reactions

-required for the production of chlorophyll

-required for formation of carbohydrates

-Required for N fixation by legumes

*Molybdenum:* availability increases as pH increases. Can be applied by limeing. Required in small amount for plants.

*Chlorine:* exists in soils as the chloridie anion (Cl-) it is known to be essential for normal plant growth, little is known about what it does to the plant. Interferes with phosphorus uptake. No known deficiencies exist, excess levels can reach toxic levels.

**Trace Nutrients required elements in minute quantities**

*Cobalt :*lack shows a stunted effect on plant growth

*Iodine:* essential to good human health, regulator of metabolism.

*Fluorine:* has minor functions in the development of useful compounds in plant juices.

Cobalt, Iodine, and Fluorine are not essential to plant life, but are important body-building materials for animals and humans

*Sodium:* closely related to potassium and where potash supply is limited sodium is absorbed in the plant as food. Active in soil water and liberates potassium and other elements

*Aluminum:* Toxic. Can be reduced by liming soils.

-Carbon, hydrogen, and oxygen account for 90% of the plants needs. These are generally obtained from CO2 and water

-These nutrients are absorbed from the soil by plants by several means:

 minerals released from decomposition of native rocks, decomposition of organic material

 Deposition with the soil from flood waters

 Application of limestone and commercial fertilizers

 Use of animal and plant manures

--And they come from the sea, rocks, soil additives, plant life

**Soil Reaction**

When we ask what is the reaction of the soil, we mean is it acidic (sometimes called sour), neutral, or alkaline (sweet)? The term pH refers to the degree of effective acidity or alkalinity (mineral salt) of a substance. The proper pH or soil reaction is important to plant because it directly affects the availability of the plant food nutrients which a plant needs for efficient growth.

--The pH measurement is a simple means by which the production potential of a soil can be evaluated. Soils that are too acid or too alkaline will not favor the solution of compounds, and restrict the presence of ions of essential plant nutrients, as many of these elements do not dissolve easily in these extreme soil conditions.

--Most plant prefer a pH of 6.0-8.0 (neutral). Below 6 is acidic, 8-14 is alkaline. The pH value indicates the chemical climate of the soil.

-Chemical characteristics of a soil are dependent on the nature of the rock in which the soil was formed.

--weathering of granite and many sandstones is typically acidic

--weathering of limestone commonly results in alkaline soils (in hot weather can become acidic as the lime can be removed from evaporation)

----Generally, soils in humid regions are acidic, in sub humid and arid climates generally alkaline or neutral

-Changing pH

--increase pH (make it less acid or to make it alkaline) calcium in the form of limestone is added

--decrease pH (make is less alkaline or make it more acid) commercial alum or sulfur is added

--------Low pH metal cations like aluminum or magnese are more soluble and can be toxic, can be eliminated by adding limestone to raise pH. Increased pH also enhances microbial activity.

6.0-6.5 is the level that plants and microbrial activity will function at the optimum level. pH helps understand that bacteria and chemical vigor of the soil. Acid soils, may be naturally acidic from rocky origin or from the acid of decaying leaves or from soil additives like aluminum. Neutralized by the addition of lime products.

-Many plants and [soil life](http://en.wikipedia.org/wiki/Soil_life) forms prefer either alkaline or acidic conditions

-Some diseases tend to thrive when the soil is alkaline or acidic

-The pH can affect the availability of nutrients in the soil

**Soil as a Water Reservoir**

-Soil directs the flow of water

-75% of rainfall ends up in soil

-Water can be retained in capillary-sized pores within the soil

-Plants require about 500 lbs of water for every pound of plant growth

-2/3 of the water is disposed of through evapotranspiration (evaporation from plant leaves and soil)

-Plants remove water throughout the root-zone

-Excess water (as in rainy seasons) contributes to the underground water supply

**Life in the Soil**

*A handful of moist, fertile soil contains more organisms that there are people on earth.*

-The most numerous are single celled bacteria

--Examples: bacteria, fungi and other *nonchlorophyllous* plants (some remove nitrogen from the air and combine it into a form plants can use: *nitrogen fixation*)

--Protozoas (feed on bacteria), worms, mites, centipedes, snails, ants, termites, gophers, earth warms soil friends!

---loosen, mix the soil

(*Study: soil critters:* The Burlese funnel;to examine your soil for small animals attach a light bulb above 4 inches of soil (about 1 day) Sd the hat from the light dries out the soil, animals are driven out and into the collecting bottle. A moist soil is ideal to- begin the study with.)

**Role of Organisms in Chemical and Water Disposal**

-Soil and soil biota cannot digest foreign chemicals (ex.DDT) and therefore the chemical moves throughout the food web

-Septic Tanks: Used for the digestion of sewage
--Use fields as filters to release effluent

---Percolates through the soil

----“recharges” underground water reservoir

-Soil organisms can destroy disease organisms and decompose waste materials in septic tank effluent water

(fields must be permeable! Filter beds are used to determine how rapidly the water is infiltrated through the ground. Filter beds with less than an inch per hour are too impermeable. Measure with measuring stick. In general, the more clay in the soil, the more permeable.)

Soil Notes from Dr Henry D Foth, Soil Handbook

**Composition of Soils**

-Factors of soil formation

**1.** living matter **2.** Climate **3.** Parent materials (fineness of particle size as well as chemical and mineralogical composition) **4.** Relief (slope and land form) **5.** Time

- Given the knowledge of the time required to develop a soil, it is of utmost importance that mankind use this natural resource in cooperation with laws of nature to optimize soil conservation.

--chemical and physical conservation, good management practices

-Clay soils, finely textured

-Loams, medium textured

-Sands, coursly textured

-Components of soils are called *fractions* (sand, silt, clay, organic fractions)

-The class names (ex. Sandy clay) is based on the relative proportions of the constitutes in the soil

-*Colloidal portion* sub-microscopic particle size, large surface area of soils, consists of highly decomposed clay and organic matter, accounts for soils capacity to hold nutrients

--these minute colloids (clay and organic) have a negative charge; they attract and hold positively charged metals, called *cations*, such as: iron, manganese, zinc, and copper

----the capacity for a soil to hold these cations is called the *Cation Exchange Capacity*

-----the capacity for a soil to hold metal cations depends on the CEC of the soil

-CEC depends on the type and percentage of colloidal clay and organic fractions

--ex) predominant sand soil, low CEC; clay CEC is high; organic matter even higher CEC

-Soils high in CEC are less subject to nutrient leaching

-The colloidal fraction of soils had a large effect on the nutrient holding capacity, water retention, and ease of tillage

-Clay: enhance nutrient and water holding capacity, binding agent, beneficial for structure, texture, and fertility

**Overcropping**

“The tillers of the soil are under a definite obligation to society to preserve the productivity of the land that is temporarily under their control”

**Organic Matter**

Benefits:

home to bacteriological organisms that are part of the biological and chemical reactions for plant life

aids in moisture retention within soil

supplies nutrient elements for plant use (especially N, and sulfur)

Increases the nutrient holding capacity of soils

Enhances soil aggregation and aeration

Improves soil tilth which makes a soil more friable

Aids in the reduction of soil erosion

W/o organic matter biological activity and the rate at which minerals are available for plant use would be greatly reduced

**Tips on Lime**

Lime in the fall. If not fall, early spring. Do not apply as top dressing after clover or alfala have been planted. 1 ton of lime per acre should last 4-10 years. May take 2 years to get full benefit. Fertilizers such as manure should never be mixed with lime but can be applied before or after lime.

Types of lime: Burnt Lime forms: quicklime (oxide, fresh, or masons lime); hydrated or slaked lime in powder form. Limestone (carbonate) forms: lump or screenings, raw rock; ground or powder form; marl or deposit lime bed, lump or ground

*Hidden hunger* will occur when our foods are not nutritious, and though we may have an abundant food source, we will not be nurturing our bodies